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EFFECT OF STATIC MAGNETIC FIELD EXPOSURE OF SALVIA SEEDS ON GERMINATION CHARACTERISTICS (*Salvia officinalis, L.)*

Martínez, E.; Carbonell, M.V.; Flórez, M; Amaya, J.M.
Dpto. Física y Mecánica. E.T.S.I. Agrónomos. Universidad Politécnica de Madrid.
Ciudad Universitaria s/n 28040 Madrid, **SPAIN**
E-mail: victoria.carbonell@upm.es

The main objective of this study is to determine the effects of magnetic treatment, in addition to the geomagnetic field, on germination of *salvia officinalis* L. seeds. This objective has a practice application in agriculture science: to obtain an early growth of salvia. A great development of crops of medicinal, condimentary and aromatic plants crops is taking place in Mediterranean countries due to their high added value as consequence of the Fitotherapy reappearance among other reasons. In recent decades magnetic treatment of seeds became very popular in agricultural sector. Salvia seeds were exposed to 125 mT stationary magnetic field generated by magnets for different time: 10 minutes (A1), 20 minutes (A2), 1hour (A3), 24 hours (A4) and chronic exposure (A5). Other group of seeds were subjected to a magnetic pretreatment (P1). Not exposed seeds were used as control (C). Germination tests were performed at temperature 20-22ºC under laboratory conditions. The selected germination parameters were: time for the first seed to germinate (T_1), time to reach 10, 25% etc. germination ($T_{10,}$ T_{25}, T_{50} and T_{75}), number of germinated seeds (G_{max}) and the mean germination time (MGT), all of them were provided by the Seedcalculator software package.

Results indicate that magnetic field application enhanced the seed performance in terms of laboratory germination, rate and percentage of germination compared to unexposed (C). The germination parameters recorded for salvia seeds and for each treatment and pre-treatment were lower than corresponding control value. Among the various treatments, chronic exposure to 125mT (A5) gave best results. Data obtained for salvia treated seeds showed that MGT was significantly reduced compared to control ones (79.68 h for A3, 81.84 h for A4, 75.60 h for A5, and 81.60 h for P1 *vs*. 95.28 h for control). Parameters (T_1-T_{50}) and MGT were also significantly reduced for treatments A2, A3, A4, A5 and P1.

1. Introduction

A great development of crops of medicinal, condimentary and aromatic plants crops is taking place in Mediterranean countries due to their high added value as consequence of the Fitotherapy reappearance among other reasons. Salvia plants are used as condimentary spice, but it has some medicinal properties due to its essential contents. They are cultivated for food, herbalist, cosmetics and liqueur industry (Muñoz, 2000).

In recent decades magnetic treatment of seeds became very popular in agricultural sector. In the last decades the number of bioelectromagnetism research reports focused upon the investigation of living organisms magnetosensitivity has increased. Plants became more and more an attractive model system for study the biological effects of magnetic fields (Racuciu and Creanga, 2005). Studies realized by Alexander and Doijode, 1995, showed that pregermination magnetic treatment improved the germination and seedling vigour of low viability rice and onion seeds. According with these works, Yinan *et al.* (2005) published that the magnetic field pretreatment had a positive effect on cucumber seedlings, such as stimulating seedling growth and development. An increased rate of germination cereal seeds exposed to magnetic field has been obtained by Pittman. Greater albumin, gluten and starch contents in wheat seeds exposed to magnetic field were obtained by Pietruszweski. A possible mechanism associated with magnetism to accelerate tomato ripening was proposed by Boe.

In previous studies, the authors have found that 125 mT and 250 mT magnetic treatment produces a biostimulation on the initial growth stages and an increase of the rate of germination of several seeds as rice, wheat, and barley (Carbonell *et al*., 2000; Martínez *et al.,* 2000, 2002; Flórez *et al*. 2004). Recently, Flórez *et al*., 2007 studied the effect of the germination of maize seeds, they concluded that the time required for germination recorded for each magnetic treatment were lower than corresponding control values, thus the rate of germination of treated seeds was higher than the untreated seeds rate. Growth data measured on 7^{th} and 10^{th} days after seeding allowed them to corroborate the effect observed in germination tests; significance differences between length and weight of maize seedlings subjected to a 125 mT and 250 mT magnetic field for different time versus control was obtained. Carbonell *et al* (2008) have observed a positive response in grass seeds; exposure to magnetic field provides an earlier germination, increases the number of germination seeds, reduces the germination rate and increases root length for *Festuca arundinacea* Schreb. and *Lolium perenne* L. seeds.

The main objective of this study is to evaluate the effect on germination of *Salvia officinalis* L. seeds of magnetic treatment, by exposing the seeds to 125 mT magnetic field for different periods of time and pre-germination exposure. This objective has a practice application in agriculture science: to obtain an early growth of salvia.

2. Objects and methods

Germination tests were carried out to study the effect of the exposure of *Salvia officinalis,* L. seeds to 125 mT stationary magnetic field. Test was performed at the summer season under laboratory conditions with natural light and the temperature average was 20 ± 2ºC.

Groups of seeds were exposed to magnetic field by varying the exposure time (A1-A5) and other group of seeds were subjected to a magnetic pretreatment (P1) for the 24 hour previous sowing. The static magnetic field was generated by permanent ring magnets with 125 mT strength. Geometrical characteristics of the ring magnet are external diameter 7.5 cm, internal diameter 3 cm, and height 1 cm. Analogous rings like the ring magnets, manufactured with the same material, but without magnetic induction, were used as blind (Control). Times of exposure were: 10 min (A1), 20 min (A2), 1 h (A3), 24 h (A4) or chronic exposure (A5). An experimental design using four replicates (n=4), with 25 seeds in each one was carried out. Thus, groups of 100 seeds were subjected to each magnetic treatment, and analogous groups were used as control.

The germination test was performed according to the guidelines issued by the International Seed Testing Association (ISTA Rules, 1999) with slight modifications; seeds were germinated by placing 25 seeds per Petri dish on filter papers soaked with 12 ml of distilled water. The seeds were placed around a circular line, in this way, all the seeds were subjected to the same magnetic field strength, when the Petri dish is placed on top of a permanent magnet. To obtain dose A5 Petri dishes were placed onto the magnets for all the experimental time, then the seeds were chronically exposed. To obtain the other doses the Petri dishes were placed onto the magnets for the corresponding time 10 min, 20 min, 1 h , and 24 h (A1-A4) or presowing magnetic treatment (P1). After that, they were placed on a blind-ring without magnetic induction. The control group of Petri dishes was located on blind-rings right from the beginning; then, the seeds were not exposed to magnetic field

Experimental groups A1-A5, P1 and control C ran simultaneously for the germination test. For each treatment the number of germinated seeds was registered three times per day for the time necessary to achieve the final maximum percentage of germinated seeds (G_{max}). Seeds were considered as germinated when their radicle was at least 2 mm long. The selected germination parameters were: time for the first seed to germinate (T_1), time to reach 10, 25% etc. germination ($T_{10,}$ T_{25}, T_{50} and T_{75}), number of germinated seeds (G_{max}), correlation coefficient (R^2) and the mean germination time (MGT), all of them were provided by the Seedcalculator software package developed for seed germination data analysis by Plant Research International.

Statistical analyses. Data of germination obtained for the magnetic treatments were compared by the t-student valued and the p-values were calculated to test for significant differences between each treatment and the control using the Seedcalculator software for seeds germination data analysis.

3. Results and discussion

Germination parameters calculated for salvia seeds, are recorded in Table 1. Results show that the percentage of germination (G_{max}) was higher for magnetically treated seeds. Parameters T_1 and T_{10} were significantly reduced for all magnetic treatment; then, the onset of the germination is produced earlier. Value of T_1 of seeds not exposed to magnetic field was 72.96 h while this value was 23.04 h for A4, 22.56 h for A5 and 25.20 h for pretreatment (P1). Significant reductions were also obtained for T_{25} parameter. The mean germination time (MGT) of salvia seeds was significantly reduced when seeds were exposed to magnetic field; the greatest differences between treated seeds and control were obtained when seeds were treated for 24 h and chronically exposed (81.84 h for A4, 75.60 h for A5 *vs.* 95.28 for control). In addition, the other parameters evaluated T_{50} and T_{75} were also reduced. In consequence, the percentage and rate of germination of salvia seeds exposed to a 125 mT stationary magnetic field was increased.

Dose	R^2	G_{max} (%)	Time (hour) $\bar{x} \pm SEM$					
			T_1	T_{10}	T_{25}	T_{50}	T_{75}	MGT
C	0.98	47 ±4.4	72.96 ±0.72	78.96 ±0.72	83.04 ±0.72	88.80 ±0.96	97.44 ±1.92	95.28 ±2.16
A1	0.96	60 ±4.3	34.08 ±9.36 **	57.36 ±9.36 *	72.96 ±7.20	90.96 ±5.28	109.9 ±5.52 *	91.92 ±5.76
A2	0.86	63 ±4.4 **	27.36 ±1.44 ****	48.24 ±2.40 ****	62.64 ±2.88 ****	79.68 ±3.36 **	97.68 ±4.08	80.64 ±3.36 **
A3	0.94	56 ±4.3	25.44 ±7.44 **	46.80 ±11.0 **	61.68 ±7.92 **	78.96 ±4.08 *	96.96 ±1.20	79.68 ±3.60 **
A4	0.97	69 ±1.9 **	23.04 ±2.88 ****	44.16 ±2.64 ****	59.76 ±2.16 ****	79.20 ±2.40 **	101.4 ±4.56	81.84 ±2.88 ***
A5	0.98	58 ±5.0	22.56 ±6.24 ****	41.28 ±2.88 ****	54.96 ±2.40 ****	72.48 ±4.32 **	92.64 ±6.48	75.60 ±2.64 ***
P1	0.94	65 ±5.3 *	25.20 ±8.16 **	47.04 ±11.3 **	62.4 ±8.16 **	80.64 ±4.56	99.84 ±2.16	81.60 ±5.76 *

Table 1. Germination parameters determined for *Salvia officinalis* L. seeds exposed to 125 mT stationary magnetic field, expressed as mean ± standard error. Exposure times were 10 min (A1), 20 min (A2), 1 hour (A3), 24 h (A4), chronic exposure (A5), pretreatment (P1) and not exposed seeds (C). G_{max}: number of germinated seeds (%); MGT: Mean germination time; T_1, T_{10}, T_{25}, T_{50}, T_{75}: time required for 1, 10, 25, 50 and 75% of the seeds to germinate expressed in hours. R^2: correlation coefficient. Asterisks indicate differences *vs*. control: ****($p<0.001$): very strongly significant; ***($0.001<p<0.01$): strongly significant; **($0.01<p<0.05$): significant; *($0.05<p<0.1$): differences.

Results obtained for salvia seeds are according with other studies about the influence of a stationary magnetic field on several seed germination and plant growth which reveal that magnetic treatment produces an improvement of percentage and rate of germination of exposed seeds. Aladjadjiyan (2002) obtained an increase in germination and shoot development when exposed maize seeds to 150 mT magnetic field for 10, 15, 20 and 30 minutes. Similar results with tobacco seeds were obtained by Aladjadjiyan and Yileva (2003). Yano et al. (2001) observed the induction of primary root curvature in radish seedlings in a static magnetic field. The roots responded tropically to the static magnetic field, with the tropism appearing to be negative, these roots responded significantly to the south pole of the magnet. Podlesni *et al*. (2004) confirmed the positive effect of the magnetic treatment on the germination and emergence of bean cultivars; plant emergence from magnetized seeds was 2-3 days earlier compared to the control, the yield was increased due to the higher number of pods per plant. Racuciu *et al.* (2006) reported that the length of young plants of maize exposed to a magnetic field varying from 50 to 250 mT, were higher than control for all exposed samples.

Figure 1. Cumulative germination curves of *Salvia officinalis*, L. seeds subjected to 125 mT stationary magnetic field for different time, (a) Doses A2, A3 and control; (b) Doses A4, A5 and control; (c) Magnetic pretatament (P1) and control curve.

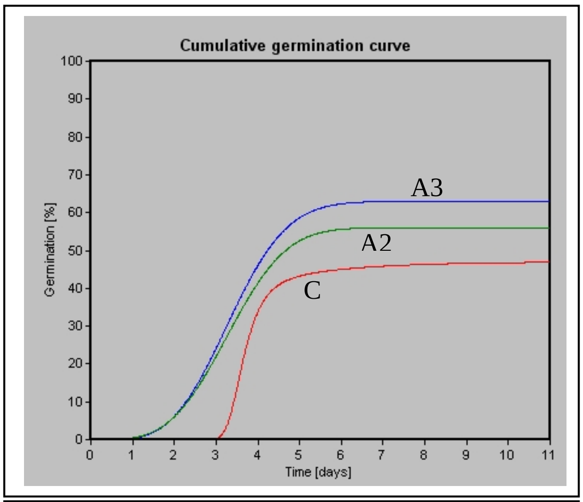

Figure 1 a. Cumulative germination curves of *Salvia officinalis*, L seeds subjected to 125 mT stationary magnetic field for 20 minutes (A2), 1 hour (A3) and control curve (C).

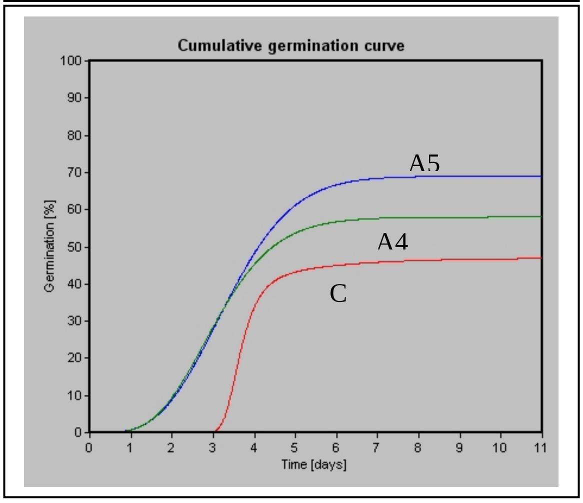

Figure 1 b. Cumulative germination curves of *Salvia officinalis*, L seeds subjected to 125 mT stationary magnetic field for 24 hours (A4), chronic exposed (A5) and control curve (C).

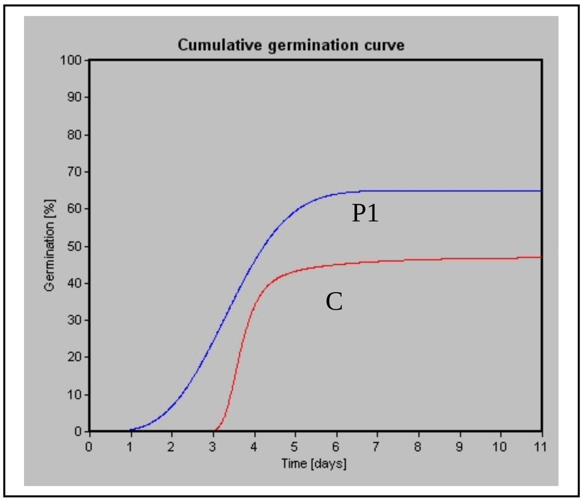

Figure 1 c. Cumulative germination curves of *Salvia officinalis*, L seeds subjected to 125 mT stationary magnetic field (P1) pre-treatment and control curve (C).

Figures1 a, b and c show that in all cases, the germination curve of control is underneath the curves of treated seeds, then, control germination rate is lower than the corresponding to all magnetic doses.

4. Conclusion

The mean germination time (TMG) and parameters T_1-T_{75} were reduced for all magnetic doses applied, then, rate of treated seeds is higher than the control. In summary, stationary magnetic field could be used as a physical technique to improve the germination of salvia seeds.

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